Transmission Strategy and Planning

Green River 610 MW Project
LGE-LGI-2007-002

Facilities Study Report
April 17, 2009

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Introduction

[redacted] submitted a request for a new generation interconnection to the Independent Transmission Organization (ITO) on February 28, 2007. [redacted] requested the addition of a 610 MW plant (Project) near the existing Green River generating facility north of Central City, KY. [redacted] requested Network Integration Resource Service from the Project to the Kentucky Utilities Company (KU) and Louisville Gas and Electric (LG&E) Network Loads. The proposed commercial operation date for the Project was June 1, 2014. [redacted] submitted the request for the System Impact Study on May 24, 2008. The ITO completed a System Impact Study on October 18, 2008. An Interconnection Facility Study Agreement (FSA) was submitted on October 30, 2008. The proposed commercial operation date for the Project has been revised to January 12, 2016 in the FSA. The ITO delegated the Facilities Study to the TO (E.ON Transmission).

Review of Generator Data

The FSA included a project description, site arrangement and an overall one-line diagram. The ITO provided Revised Appendix 1 data that was submitted for the Project on June 8, 2007. A review of the data identified numerous discrepancies for the generators and generator step-up transformers that required resolution by [redacted] before the Facility Study could begin. Additionally, the Project data did not include the auxiliary load requirements necessary for the stability assessment.

[redacted] submitted corrected generator and generator step-up transformer data and provided auxiliary load data on December 17, 2008. It was determined during the development of the stability models that the governor data for the combustion turbines was not legible. Legible data was requested on January 16, 2009 and received on February 6, 2009.

ITO Power Flow Model Review and Update

The ITO performed the System Impact Study using a NERC 2016 summer power flow model that was developed in 2006. The ITO's model development process is to incorporate all prior generator requests and transmission service requests into the "base case model" that is used for the analysis of the project.

On January 12, 2009, E.ON Transmission requested documentation of the changes made by the ITO to the NERC 2016 summer power flow model associated with the prior generator requests and transmission service requests. The ITO provided this documentation on March 30, 2009. The lack of response required E.ON Transmission to perform its own analysis of the case changes. The modifications to the ITO case are documented in Appendix A and described below:

TSR 2006-006 KMPA

Added the 5% reactor in the Grahamville – C33 161 kV line

TSR 2006-007 LGEE to MISO

Point to Point transmission service has been reserved on the LGEE transmission system but has not been accepted long-term on the MISO system. This 52 MW interchange was removed to be consistent with the NERC base case development process and E.ON's Transmission Planning Guidelines.

TSR 2006-009 LGEE to PJM

Point to Point transmission service has been reserved on the LGEE transmission system but has not been accepted long-term on the MISO system. This 52 MW interchange was removed to be consistent with the NERC base case development process and E.ON's Transmission Planning Guidelines.

TSR 2006-012 UPS

TSR 2006-013 Lemons Mill

TSR 2006-014 Lexington NW

The customer has changed the location of the tap from the 69 kV to the 138 kV. The load at 11LEXNW 69 was moved to 11HAEFLN 138.

TSR 2006-015 Higby Mill 69

The customer has changed the location of the tap from the 69 kV to the 138 kV. The load at 11higb2 69 was moved to 11HIGBY 138.

The model was changed accordingly.

TSR 2006-016 Lexington East

The customer has canceled the new station and will be adding capacity at Bryant Road. The load at 11LEX E 69 was moved to 11BRYANR 69.

TSR 2007-001 Airgas

TSR 2007-002 Lebanon East

Interchange

The case included an additional purchase of 101.5 MW (50% AEP-50%TVA); this was removed.

Load

The load in the base case was increased 142 MW due to the new load requests submitted by the E.ON LSE. These requests are considered to be included in the annual forecast. The TO has proposed to the ITO that the model development process include system-wide load reduction to offset the load increase. A system-wide load reduction of 142 MW was incorporated into the case.

Green River – Paradise 161 kV line

The impedance of the Green River to Paradise 161 kV line was revised to be consistent with the length estimated length of 13.3 miles:

SIS Impedance	R=0.00230	X=0.02210	BC=0.02300
FS Impedance	R=0.00283	X=0.02692	BC=0.02808

Green River 161-138 kV transformers

The ITO model included four 161-138 kV transformers at Green River. The LGI-2007-001 Facility Study concluded that replacing the three existing 120 MVA transformers with 150 MVA transformers will provide sufficient transformer capacity and be more economical because the installation of a fourth 161-138 kV transformer would require reconfiguration of the 138 kV station, an additional bay in the 161 kV station, breaker additions at both voltages and construction of a 161 kV line between the two stations with numerous line crossings. The model was revised to include three 150 MVA transformers with an impedance of 5% at 150 MVA.

Green River – Ohio Co 138 kV #2

The line impedance was corrected and the rating was updated.

EKPC Central Hardin 138-69 kV transformer

EKPC plans the construction of a 138-69 kV substation that significantly reduces the flow on the Hardin Co – Elizabethtown 138 kV and Hardin Co – Elizabethtown 69 kV lines.

Miscellaneous Ratings Updates

The rating of facilities that were overloaded in the contingency analysis were reviewed. Ratings that have been revised were incorporated into the base case.

Generator-Transmission Point of Interconnection

The Facility Study Agreement indicates that [redacted] will construct all 161 kV station facilities at their generating site and two 161 kV lines from the generating site to the Point of Interconnection at the Green River 161 kV station. The two lines from the Generator will connect to the Green River 161 kV station at the two points indicated by "Gen" on the diagram in Appendix C. Interconnection metering will be located at each of these Points of Interconnection.

The stability analysis for LGE-LGI-2007-001 evaluated the impact arrangement of the line and transformer connections to the Green River station. The arrangement recommended in that study was utilized in this analysis.

Power Flow Contingency Analysis

The contingency analysis included the simulation of all single branch contingencies 100 kV and above in E.ON and BREC simultaneous with the following generation contingencies; Base Case, Green River 4, Brown 3 and Mill Creek 4. The replacement generation required for the generator contingency was imported from TVA. The worst case flows on impacted facilities that exceed the facility rating are shown Appendix B.

Stability Model and Analysis

The stability analysis was performed using the NERC 2011Summer power flow and dynamic files provided by in the NERC 2006 base case series. These are the files utilized by the ITO in its analysis.

The stability analysis evaluated the transient angular stability of the local generators, once a fault occurs close to the Green River 161 kV (GR 161kV) bus, assuming that the new generators at Green River are added into the system. The new generators are expected to be put into service beginning on January 2016.

For the purpose of performing system impact analysis, faults were simulated. The faults are simulated as follows:

Three Phase Sustained Fault (3-ϕ)

The fault started out as a three phase fault on a certain section of the line or transformer. After five cycles the remote end of the faulted line or transformer is

tripped. The simulation continued, assuming that one of the breakers located between the faulted element and the bus failed to open all three poles, thus maintain a three phase fault.

Initial Three Phase Fault (5 Cycles) Followed By a Sustained Single Phase-to-Ground Fault (ϕ-to-grd)

The fault started out as a three phase fault on a certain section of the line or transformer. After five cycles the remote end of the faulted line or transformer is tripped. The simulation continued, assuming that one of the breakers located between the faulted element and the bus failed to open one of the three poles, thus maintain a single phase-to-ground fault.

Transient angular stability analysis was performed to determine the critical clearing time (CCT), which is the maximum acceptable time to clear the fault where local generators remain stable. In the process of determining the CCT, the duration of the fault is incremented by 0.5 cycles. The results are shown in the table below. Layout of the breakers for stuck breaker study is provided in appendix C.

The angular stability study also verified that the local generators are positively damped for small-signal disturbances.

Critical Clearing Time (CCT), in Cycles, For Different Scenarios of Stuck Breaker.

Fault Location	Stuck Breaker*	3-ϕ CCT	ϕ-to-grd CCT
Green River to Paradise 161 kV	D	9	15+
Green River to River Queen Tap 161 kV	D	9	15+
Green River to River Queen Tap 161 kV	E	9.5	15+
Green River to Wilson 161 kV	C	9	15+
Green River to Corydon 161 kV	C	9	15+
Green River to Corydon 161 kV	F	9.5	15+
Green River 161 kV - 138 kV Xfmr	A	9.5	15+
Green River 161 kV - 138 kV Xfmr	B	9.5	15+
Green River 161 kV - 138 kV Xfmr	E	9.5	15+
Green River 161 kV - 138 kV Xfmr	F	9.5	15+
Green River to Green River New 161 kV	B	9.5	15+

* The failure of other breakers was assessed to be less severe.

The existing 161 kV breakers at Green River are gang operated. A single mode failure of a gang operated breaker can result in a sustained three phase fault that cannot be cleared in the required 9-9.5 cycles. Therefore, all the existing 161 kV breakers must be replaced with breakers that have independent pole operating mechanisms. The breakers that must be replaced because of the stability requirements are shown in the following table:

Required Breaker Replacements

Station	kV	ID
Green River	161	864
Green River	161	868
Green River	161	872
Green River	161	878
Green River	161	884
Green River	161	888

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Short Circuit Model and Analysis

The ITO used a short circuit model that was developed for the LGI-2007-001 System Impact Study. A short circuit model was developed for that study from the three BREC, E.ON, TVA Company models because there was not a comprehensive model including the three Companies available at the time of the ITO SIS. The ITO did not request an update at the time of the LGI-2007-002 System Impact Study. The breaker replacements identified in the SIS report were based on a simplified calculation: (base case breaker duty* (post-case bus fault level/base-case bus fault level)).

The SERC SCDWG developed a short circuit model of 2008 summer during the spring of 2008 that includes representation of BREC, E.ON, TVA. E.ON's current short circuit model was developed by replacing the EON equivalent in the SERC 2008 summer model with a detailed model of EON. The current E.ON model with all planned modifications to the system prior to the addition of the new plant was used in the Facility Study analysis. This is the "Before" case.

The Facilities Study examined the impact of connecting the new generation to the transmission system, constructing new 161 kV line from Green River to TVA's Paradise plant and replacing the 3 161-138 kV transformers at Green River. A short circuit case was prepared that reflected these modifications. This is the "After" case.

The maximum short circuit current exposure (referred to as the "duty") for each breaker was determined based on the simulation of the branch faults and expressed as a percentage of its short circuit interrupting capability. Breaker interrupting capabilities are determined in accordance with ANSI/IEEE Standard C37.010-1979.

A breaker with a change in duty greater than or equal to 5% expressed as a percentage of capability is designated for replacement if the "After" duty is greater than or equal to 95% and the "Before" duty is less than 95%. The breakers that must be replaced because of short circuit requirements are shown in the following table:

Required Breaker Replacements

Station	kV	ID
Green River	161	878
Green River	161	884
Green River	161	888
Green River	138	708
Green River	69	610
Green River	69	628
Green River	69	634
River Queen	69	624

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Project Costs and Completion Timeframes

The cost and time frame required for the equipment, engineering, procurement and construction of the necessary facilities is shown in Appendix D. The estimated cost to provide the service requested by [redacted] is $76.1 million. The time required to complete the necessary construction and upgrades is 40 months.

Construction and Upgrades of Other Transmission Owners

Construction of facilities is required by other Transmission Owners. The participation of the other Transmission Owners in the ITO's SIS process is not considered a commitment by the other Transmission Owners to construct the identified facilities. Agreements must be negotiated with the impacted Transmission Owners before the identified construction and upgrades of E.ON transmission facilities can be considered appropriate, necessary and adequate to provide the service requested by [redacted]. Appendix D does not include the cost of or timeframe necessary to complete the facility upgrades and/or construction required by TVA.

Appendix A
ITO case modifications

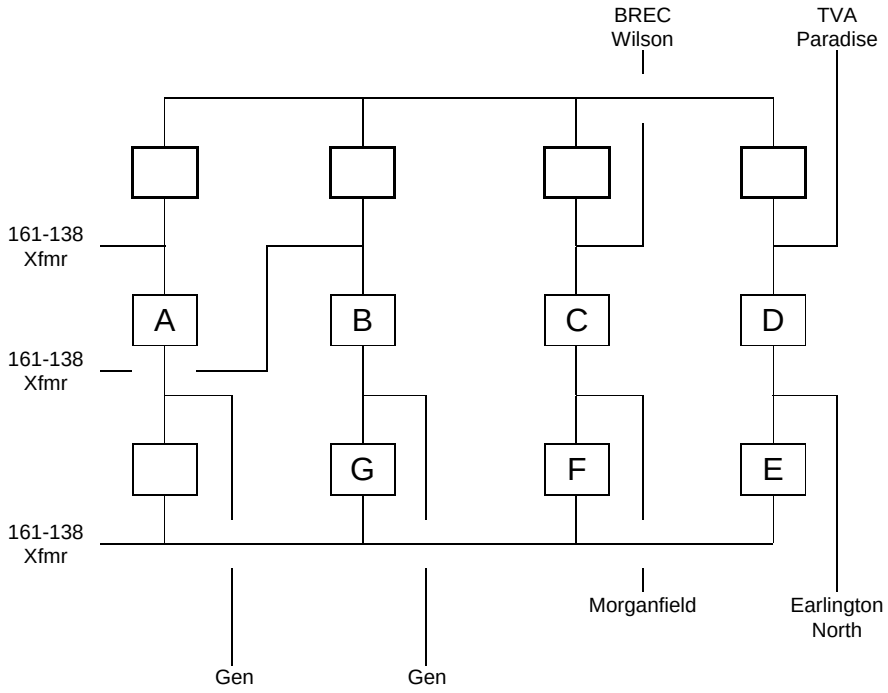
```
#balance area interchange in the case
psspy.area_data(416,_i,[-9.0,_f],r"""TECO""")

#add Green River aux load to get net plant output to 610 MW
psspy.load_data(27992,r"""1""",[_i,_i,_i,_i],[ 16.0, 8.0,_f,_f,_f,_f])

#remove the fourth 161-138kV, 120 MVA transformer at Green River
psspy.two_winding_data(27191,27192,r"""4""",[0,_i,_i,_i,_i,_i,_i,_i,_i,_i,0,0,_i,_i,_i],[_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f
,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f],r"""161-138-""")

#replace the three 161-138kV, 120 MVA transformer at Green River with 150 MVA
psspy.two_winding_data(27191,27192,r"""1""",[_i,_i,_i,_i,_i,_i,5,_i,_i,_i,0,0,2,2,_i],[ 0.002, 0.05, 150.0, 161.0,
161.0,_f,_f,_f, 150.0, 172.0,_f,_f,_f,_f,_f,0.0,0.0,_f,_f,_f,_f,_f,_f],r"""161-138-1""")
psspy.two_winding_data(27191,27192,r"""2""",[_i,_i,_i,_i,_i,_i,5,_i,_i,_i,0,0,2,2,_i],[ 0.002, 0.05, 150.0, 161.0,
161.0,_f,_f,_f, 150.0, 172.0,_f,_f,_f,_f,_f,0.0,0.0,_f,_f,_f,_f,_f,_f],r"""161-138-2""")
psspy.two_winding_data(27191,27192,r"""3""",[_i,_i,_i,_i,_i,_i,5,_i,_i,_i,0,0,2,2,_i],[ 0.002, 0.05, 150.0, 161.0,
161.0,_f,_f,_f, 150.0, 172.0,_f,_f,_f,_f,_f,0.0,0.0,_f,_f,_f,_f,_f,_f],r"""161-138-3""")

#update the Green River - Paradise 161 kV line
psspy.branch_data(18012,27192,r"""1""",[_i,_i,_i,_i,_i,_i],[ 0.00298, 0.02834, 0.02955, 529.0,
558.0,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f])

#update rating of the Daviess Co - Wilson 345 kV line
psspy.branch_data(27561,27977,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 956.0, 956.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])

#update ratiings of overloaded facilities to current FRP ratings
psspy.branch_data(26974,27195,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 359.0, 382.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
psspy.branch_data(26942,27315,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 287.0, 337.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
psspy.branch_data(26942,27546,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 231.0, 287.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
psspy.branch_data(26988,27544,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 210.0, 210.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
psspy.branch_data(26988,27544,r"""2""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 210.0, 210.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
psspy.branch_data(27144,27228,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 56.0, 56.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
psspy.branch_data(27256,27481,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 69.0, 69.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
psspy.branch_data(27472,29687,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 49.0, 49.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
psspy.branch_data(26985,29677,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 26.0, 26.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
psspy.branch_data(27424,27533,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 47.0, 47.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])

# scale LGEE area load
psspy.bsys(0,0,[0.0, 999.],1,[211],0,[],0,[],0,[])
psspy.scal(0,0,1,[0,0,0,0],[0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0])
psspy.scal(0,1,2,[1,0,1,0],[ 9046.6, 8872.0,0.0,0.0, 930.2,0.0, 2772.7])

#remove 52 MW transaction to MISO
psspy.area_data(210,_i,[-190.0,_f],r"""SIGE""")
#remove 52 MW transaction to PJM
psspy.area_data(25,_i,[ 19060.,_f],r"""PJM500""")
#correct 51 MW transaction to TVA
psspy.area_data(147,_i,[ 525.0,_f],r"""TVA""")
#correct 51 MW transaction to AEP
psspy.area_data(205,_i,[ 2754.0,_f],r"""AEP""")
#offest four transaction changes with LGEE
psspy.area_data(211,_i,[-582.0,_f],r"""LGEE""")
```

```
#move Lexington NW 69 kV load to Haefling 138
psspy.load_data(27046,r"""1""",[_i,_i,_i,_i],[0.0,0.0,_f,_f,_f,_f])
psspy.load_data(27205,r"""2""",[_i,_i,_i,_i],[ 50.904, 16.728,_f,_f,_f,_f])

#Move Lexington East 69 kV load to Bryant Rd 69 kV
psspy.load_data(27593,r"""1""",[_i,_i,_i,_i],[0.0,0.0,_f,_f,_f,_f])
psspy.load_data(27591,r"""2""",[_i,_i,_i,_i],[ 35.839, 7.6405,_f,_f,_f,_f])

#Move Higby Mill 69 kV load to Higby Mill 138 kV
psspy.load_data(27219,r"""1""",[_i,_i,_i,_i],[0.0,0.0,_f,_f,_f,_f])
psspy.load_data(27222,r"""2""",[_i,_i,_i,_i],[ 15.064, 4.4701,_f,_f,_f,_f])

#EKPC Central Hardin 138-69 kV transformer (Kargle)
psspy.ltap(27211,27213,r"""1""", 0.95,27993,r"""KARGLE TAP""", 138.0)
psspy.two_winding_data(27993,29377,r"""1""",[_i,_i,_i,_i,_i,_i,_i,_i,_i,27993,_i,0,0,_i,2,_i],[ 0.00136,
0.05000,60.0,0.975,138.0,_f,_f,69.0, 96.0, 126.0,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f],"")

# add a 5% reactor in Grahamville - C33 161 kV (2006-006)
psspy.branch_data(18035,27198,r"""1""",[_i,_i,_i,_i,_i,_i],[_f, 0.054,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f])

# correct impedance and rating of Green River - Ohio Co 138 kV ckt2
psspy.branch_data(27191,27367,r"""2""",[_i,_i,_i,_i,_i,_i],[ 0.015, 0.0628,
0.0166,172,215,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f])
```

Appendix B
Worst Case Overloads

Facility	Contingency	Dispatch	Rating	Max
11GR RVR 138-11GR STL 138 1	14WILSO7 345-11DAV CO 345 1	mc4_tva	175	179.55
11GR RVR 138-11OHIO C 138 1	11GR RVR 138-11OHIO C 138 2	br3_tva	176	180.59
11OHIO C 138-11SHREWS 138 1	11HARDN 345-11DAV CO 345 1	br3_tva	168	185.22
11OHIO C 138-11OHIO C 69 1	11OHIO C 138-11SHREWS 138 1	br3_tva	86	86.07
11ETOWN 69-11HARDN 69 1	11ETOWN 138-11HARDN 138 1	br3_tva	180	212.31
11ETWN 4 69-11HODGEN 69 1	11ETOWN 138-11NELSON 138 1	br3_tva	51	63.40

Appendix C
Proposed Green River 161 kV Station Configuration



Appendix D
Transmission Owner's Interconnection Facilities and Network Upgrades,
Cost and Timeframes

Facility	2008$	Months	Installed Cost
Reconfigure Green River 161 kV	4,300,000	24	5,762,400
Relocate Green River 161 kV lines for 161 kV station reconfiguration	2,442,250	16	3,272,800
Replace 3 Green River 161-138 kV, 120 MVA transformers with 150 MVA units	6,630,000	30	8,884,800
Add 161 kV line exit at Green River for the Green River to TVA Paradise 161 kV line	800,000	18	1,072,100
Construct Green River to TVA Paradise 161 kV line (13.4mi)	19,500,000	40	26,131,900
Reconductor Green River-Green River Steel 138 kV with 954 kcm ACSR or add 2nd 397.5 kcm ACSR .	8,792,700	36	11,783,100
Upgrade Green River-Ohio Co138 kV ckt1 to 212F	2,600,000	16	3,484,200
Upgrade Ohio Co-Shrewsbury 138 kV to 212F	4,650,000	24	6,231,400
Replace two 69 kV 600A disconnects to increase capacity of Ohio Co 138-69 kV.	75,000	8	100,500
Reconductor Elizabethtown-Hardin County 69 kV with 2-795 kcm ACSR	1,900,000	12	2,546,200
Replace breakers due to Stability and Short Circuit requirements	1,840,000	18	2,465,800
			71,735,200